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DISEASES OF ALFALFA IN CALIFORNIA



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Scald damage results from a combination of high temperatures and excessive irrigation.

Alfalfa diseases are in many instances the limiting factor in maintaining a profitable stand in California.

Yield and quality of both hay and seed may be greatly reduced by attacks of organisms upon leaves, stems, and roots.

It is important that a disease be identified before control is attempted because suggested treatments for one disease may differ greatly from those recommended for another.

This circular describes and illustrates the most important alfalfa diseases in California—their distribution and seasonal occurrence—and makes control recommendations where possible.

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Cover photograph, left and right, shows alfalfa infected by downy mildew. Center plant is resistant.

ALFALFA DISEASES IN CALIFORNIA

BACTERIAL WILT

(See color plates, pages 10–11.)

Bacterial wilt is one of the most important diseases of alfalfa in California and in the United States as a whole. It was first found in California in 1925, and is now known to be present in all alfalfa-growing areas of the state. The disease is caused by the bacterium *Corynebacterium insidiosum*. In many areas, alfalfa plants are killed so rapidly that the stands become unprofitable in three or four years. No other plants are common hosts of this organism in nature.

Symptoms. The first symptom is a stunting of the infected plants, as shown by small leaves and stems, and slow recovery after cutting. When compared with healthy plants, diseased ones often show an increase in number of stems produced. Stunting is rapidly followed by

yellowing of leaves. In early stages of the disease, the margins of the leaflets near the growing point are yellow. As the disease progresses, the entire leaflet may be yellowed, with the exception of the area adjacent to the main leaf vein. In late stages, wilting of the leaves may be evident during periods of water stress. Following wilting, leaflet margins often die, and become gray to tan in color. In the root and crown there is a yellow-brown discoloration of the central woody cylinder, which, in early stages, appears only as a ring in the outer woody tissue. In advanced stages, brown color may show in all parts of the wood. When the bacteria invade the region between the wood and bark, discoloration may be seen by peeling the bark from the woody cylinder. Pockets of yellow-brown tissue are often present on the inner surface of the bark in such cases.

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Plants in California become infected when bacteria gain entrance through wounds in the stems, crowns, or roots. Bacteria may be carried from diseased to healthy plants by implements such as mowers and rakes, and by renovating equipment. Water can distribute the bacteria in the field as they are released from wounded, diseased plants or from those in the final stages of breakdown as a result of bacterial invasion of the bark tissues. After gaining entrance, the bacteria spread throughout the plant by means of the water-conducting elements of the woody tissue. Plants usually die five to eight months after infection.

Losses from bacterial wilt are caused by lowering of plant vigor and thinning of the stand by death of plants. Thin stands permit rapid weed infestation and, in turn, result in a lowering of hay quality as well as additional weed control costs.

Control. Chemical or cultural methods of control are difficult as indicated by the rapid spread of the disease throughout the alfalfa-growing areas. The bacteria are capable of remaining alive in dry plant parts for several months; consequently, any equipment used in hay production could carry the bacteria into new fields. Trucks and balers may carry infested plant parts over long distances. Proper management of the field to prevent undue injury to the roots and crowns of the plants will help reduce spread of the disease. Resistant varieties offer the only practical means of control. The variety Caliverde, developed in California as an improved California Common, is highly resistant and is adapted to those areas of the state where California Common has been grown in the past. (Other resistant varieties grown in California are Lahontan, Buffalo, and Ranger.) Crop rotation is of benefit because the disease-producing organism can be completely eliminated from an infested field of alfalfa by destruction of the old stand and the planting of other

crops for a two-year period. Complete destruction of the old alfalfa plants is necessary.

DWARF

(See color plate, page 10.)

The dwarf disease of alfalfa was first reported in California in 1929. It is distributed from Stanislaus County south through the San Joaquin Valley, and occurs in the southern alfalfa-producing regions other than the desert areas. The disease was recently found in the central Sacramento Valley. It is caused by a virus commonly referred to as Pierce's virus.

Symptoms. Infected plants gradually decline in vigor over a period of several months, and show very slow recovery after cutting. There is an excessive number of small, spindly stems with small, dark-green leaves—usually darker green than those of healthy plants in the same field. Plants die six to eight months after infection.

The internal symptom is a brown to yellow discoloration in the woody portion of the crown and roots. The color results from deposits of gumlike materials in the water-conducting elements. During winter and early spring the discoloration does not extend completely to the bark. This symptom is similar to that produced by bacterial wilt except that, with dwarf, no discolored pockets of tissue extend into the bark. Both top and root symptoms must be carefully examined to diagnose dwarf and bacterial wilt correctly. Final diagnosis may have to depend upon microscopic examination and attempts to isolate the wilt organism.

The virus is carried from diseased to healthy plants by any of several leafhoppers in the group known as sharpshooters. When these leafhoppers feed on a dwarf-diseased plant, they take the virus into their bodies and retain it for several months. It may then be injected into other plants through the mouth parts of the leafhopper in the process of feed-

ing. Movement of leafhoppers carrying the virus is the only known method of spread of the disease.

Many other plants are hosts of this virus, including some grasses, legumes, shrubs, and vines. Grape is the only other important host exhibiting a diseased condition when infected. On grape the infection is known as Pierce's disease.

Control. The only practical means of controlling dwarf is by the use of resistant varieties. A source of resistance was found to be present in the variety California Common. Many selections were made and tested for resistance, and the better lines were composited and released as the variety California Common 49, in 1949. This line is the only known source of a practical degree of resistance. Resistance is now being incorporated into the Caliverde variety.

MOSAIC

Alfalfa mosaic, a virus disease which causes a yellow mottling of the foliage, is extremely widespread in alfalfa.

Symptoms. Leaves may show two common types of yellowed areas (mosaic patterns) in the otherwise green tissues. One type of mottle consists of yellow rings from which tapered, yellow streaks extend outward; the other type is characterized by yellow blotches or streaks between the main lateral leaf veins. Some affected plants show considerable stunting during the cooler portions of the year. During the summer months, however, very few symptoms can be seen. The disease is of little economic importance on alfalfa, but transmission of the virus from alfalfa by aphids may result in severe damage to other host plants.

Control. No control is practiced in alfalfa.

FUSARIUM WILT

(See color plate, page 11.)

Alfalfa Fusarium wilt was first described in 1927, and is now widespread in the southern half of the United States. In California the disease is known in

Leaves showing extensive alfalfa mosaic. The light areas between the veins are yellow on growing plants.



nearly all of the southern alfalfa areas. and in 1950 it was found to be established in the San Joaquin Valley. Since that time it has spread throughout the central valleys. The disease is caused by a soil fungus, *Fusarium oxysporum f. medicaginis*.

Symptoms. The first evidence of the disease is a rapid wilting of stems on one side of the plant. The wilting is followed by bleaching of the affected stems and leaves, often with the development of a slight pink color. The remainder of the plant is killed over a period of two to three months. The woody cylinder of the root and crown branches shows one or more streaks of brown to dark-red color where the fungus has invaded the tissues. These streaks may enlarge and merge until the entire outer portion of the cylinder is discolored and the plant dies.

Infection occurs through the small roots, and progresses through the water-conducting elements of the wood. Because the fungus can survive in soil for extended periods in the absence of alfalfa, rotation is of little effect in controlling the disease. A few other legumes are known to be slightly susceptible to this form of *Fusarium*, but alfalfa is the principal host.

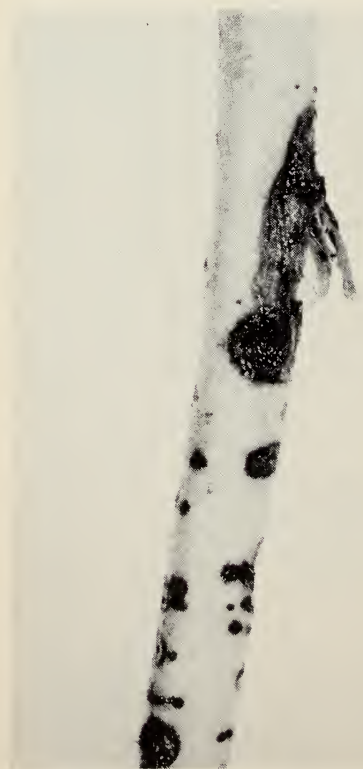
The distribution of diseased plants in alfalfa fields differs from that of other common hosts attacked by *Fusarium* in California. In alfalfa, the disease may occur in irregularly shaped areas, as with other hosts, but only a relatively small percentage of scattered plants in those areas shows disease symptoms at any one time. The greatest loss of plants occurs in the first two years, followed by death of scattered plants over the remaining years of the life of the stand.

Control. Tests show that one reason for the longevity of some of the plants in the infested areas is the fact that these plants carry resistance to the disease. Such plants have been found in most of the commercial varieties. Selections from these varieties appear to be the most practical means of developing resistance. This is the only efficient method of controlling *Fusarium* wilt.

RHIZOCTONIA ROOT CANCER

Rhizoctonia root canker disease in California is distributed widely throughout the irrigated desert regions which include the Imperial, Palo Verde, and Coachella valleys. Stand losses as a result of this serious disease may vary from 10 to 40 per cent and higher in some fields.

The disease is caused by the fungus *Rhizoctonia solani*, a normal soil inhabitant. The organism has many different strains, and one of them appears to have a specialized ability to cause cankers on the roots of alfalfa. Only isolates of this strain, obtained from affected plants during the active stage, have been capable of



Rhizoctonia root canker. Surface of taproot was scraped to show black lesions more clearly.

reproducing the disease although many other strains of *Rhizoctonia* may be found on the roots and crowns. This fungus is capable of vigorous attack on other crops, causing pre-emergence and postemergence seedling loss.

Rhizoctonia grows most rapidly in the laboratory at temperatures of about 80° to 87° F, and will grow at temperatures well above 100° F. In the irrigated desert areas affected, high soil temperatures prevail from July to October.

Symptoms. Affected areas in the field may be circular or irregular in shape. In many cases the disease is more prevalent in the wheel tracks made by farm implements. Since all affected plants seldom die at the same time, the field has a rather spotty appearance, with some plants tall and vigorous, some small, others wilting. This characteristic helps to differentiate root canker from scald caused by water standing in low spots during very hot weather. Fields affected by scald usually show uniform kill of the plants in the affected areas.

Plants with root canker have no predominant or identifying leaf symptom. Taproots of affected plants are covered by a large number of cankers which may be oval to round in shape, and yellow to tan in color. These cankers may be from about 1/4 to 1/2 inch in diameter, and commonly occur at the points where lateral roots emerge from the taproot. Sometimes the canker completely girdles the taproot. In many cases the border of the region is slightly darkened in comparison with the diseased tissue in the center. The plant is damaged most by cankers formed on the crown. During the winter months when the soil temperatures decrease, the affected areas on the taproots of some plants heal, and the lesions turn dark brown to black in color. At this time the fungus is inactive on the roots, and usually cannot be isolated.

Control. As yet, no adequate methods of control have been found. A search for resistant plants has been made. Progeny

from some selected plants, while not truly resistant, show promise of being more vigorous and longer lived than the existing varieties. In the irrigated desert valleys, growers have successfully re-established alfalfa stands by replanting infested fields in October or November.

RHIZOCTONIA STEM CANKER

This stem disease is of minor importance in most areas. It also is caused by certain strains of *Rhizoctonia solani*. The fungus attacks the crown and stem tissues just below the soil line, but the stem canker may extend an inch or more above the soil surface. Areas of the canker vary in color from tan to dark brown. Attacked tissues die, causing yellowing and wilting of the leaves and tips of the stems. The disease is most evident in first- or second-year plantings and in the spring, early summer, and fall.

PHYTOPHTHORA ROOT ROT

(See color plate, page 11.)

First found in Yolo County in 1952, this disease now occurs in nearly all the alfalfa-producing areas. It is one of the most serious diseases of alfalfa in California.

The disease is caused by the water mold fungus, *Phytophthora cryptogea*, which is favored by wet soils. There is good evidence that the swimming stage (zoospore) needs free water for initiation of root infection. The fungus may be spread from field to field in water or on soils. In the laboratory, the organism grows well at temperatures from 70° to 80° F. Growth is extremely slow at 91° F, and ceases at 95° F. Root rot may occur at soil temperatures between 62° and 81° F. In the Imperial Valley the disease is more active in the fall, winter, and spring than in the summer. In other parts of California it is most prevalent in the spring, summer, and fall.

In fields where the disease is found and where the fungus is quite active, reduced yields are caused by a stunting ef-

fect and by death of plants in the affected area. This *Phytophthora* species has not been found in the field on any crops other than alfalfa. However, the species has been known only a short time, and other crops may be susceptible. Garbanzo beans and sesbania are both susceptible in greenhouse tests.

Symptoms. Leaves of plants affected by *Phytophthora* root rot become yellow and drop. Many plants wilt and soon die. The lesions on the taproots are usually irregular in shape, and vary in color from a reddish-brown in the early stage to yellow-tan in the advanced stage. Finally, as the disease progresses, the affected tissues become dark brown to black, and cannot be distinguished from other crown and root diseases.

Isolation of the causal fungus has always been somewhat difficult and has been most successful from tissue in the beginning stage of infection, consequently selection of plants for identification of the disease by isolation methods should be made from those showing early top symptoms.

Control. Some control is possible through careful irrigation practices. The disease has been found mostly on soils of high moisture-holding capacity with poor drainage. In many such instances, it has been found that land has been irrigated too frequently or too excessively. However, the disease has also been seen in some sandy, well-drained soils. A search for a source of resistance to this fungus has been encouraging, but a resistant variety is not yet available.

STAGONOSPORA ROOT AND CROWN ROT

(See color plate, page 11.)

This disease has been known in California since 1938, and seems to vary in severity from year to year and from field to field. It does not seem to be uniformly distributed over a large number of fields, but in areas where it is active, with a

high proportion of infected plants, the loss may be very important. Limited to alfalfa and sweet clover, the disease has been found at one time or another in nearly all the alfalfa-producing areas of California.

The disease is caused by a slow-growing fungus, *Stagonospora meliloti*, which does best at 60° to 77° F. The fungus appears to enter the plant primarily through the stem tissue, and progresses slowly downward into the taproot. Occasionally, lesions are found on the taproot 3 to 5 inches below the crown.

Symptoms. The bark tissue on the roots and crowns of plants with root lesions is commonly cracked and irregular in shape. The affected root does not usually rot until two to four months after infection has begun. Lengthwise sections through the rotted area show affected bark and xylem tissue with bright reddish-brown flecks, from which the fungus can be isolated. This symptom readily identifies the disease. Occasionally, reddish-brown discoloration may be associated with other diseases, such as bacterial wilt or *Phytophthora* root rot, but neither of these shows the reddish flecking characteristic of *Stagonospora* root rot. This fungus may also produce leaf spots under certain conditions (see "Minor Fungus Diseases," p. 14).

Control. The soil environment is extremely unfavorable for the fungus, and it is not a good soil inhabitant. Thus a two- to three-year rotation is indicated as an effective control. Little work has been done to find a resistant variety. In limited tests, the variety Africa was more susceptible, and Atlantic less susceptible, than California Common.

PHYMATOTRICHUM ROOT ROT

This disease is also known as cotton root rot, Texas root rot, or *Ozonium* root rot. It is caused by a fungus, *Phymatotrichum omnivorum*, reported to be native to desert soils of Arizona. In Cali-

fornia, the fungus is found only in the Palo Verde, Coachella, and Imperial valleys, and is not widely distributed. In addition to alfalfa, all other broad-leaved crops that grow during the hot summer in the desert valleys are affected. During the winter months the disease is not a problem, and various winter crops can be grown successfully on infested land.

Symptoms. The fungus may be distributed in the soil to a depth of 8 feet, in the form of small, irregularly shaped masses of tissue (sclerotia) which can often be seen without magnification. In this form, the fungus can survive in the soil for long periods of time in the absence of host plants.

The presence of *Phymatotrichum* in the soil may also be indicated by irregularly shaped spore mats which sometimes appear on the surface. These are white in the early stage, becoming buff colored later. The masses of small spores making up these mats do not germinate, and apparently have no function. They seldom occur unless there is a period of summer rain.

Tops of infected plants do not show symptoms other than the stunting that results from the root rot. Infested areas show up as circles of dead plants, the centers of which are sometimes not affected. Lesions on the taproots are yellow to brown in color, sunken, quite clearly defined, and more irregular in shape than those of *Rhizoctonia* root canker.

Control. A rotation of at least three years with a nonsusceptible crop will reduce the population of the fungus. Because of the distribution of the fungus in the soil, complete eradication has not been possible by chemical means. To date no reports of resistance in alfalfa have been made. There is some evidence that use of 10 to 20 tons of manure per acre, or large applications of ammonium sulfate, will reduce the incidence of the disease. Plowing under green manure crops such as papago peas has been helpful in reducing the fungus population.



Crown wart. Note the large, infected buds on crown branches.

CROWN WART

The crown wart disease of alfalfa is caused by the fungus *Urophytyctis alfae*. It is most common in the northern half of California, in heavy, wet soils.

Symptoms. As the name implies, the primary symptom is the formation of irregularly shaped, white galls on the crown near the soil surface. As the galls mature, they become gray to brown in color. If a gall is cut open, brown fungus spore masses can be seen. The galls result from fungus invasion of the developing buds of the crown branches. The presence of the fungus completely changes the normal buds to form the galls which may vary from $\frac{1}{8}$ to 2 inches in diameter. The disease is evident in the spring; later in the summer the galls disintegrate and the spores are released into the soil.

Control. No control measures are practiced as the losses from this disease are usually minor.

SOUTHERN ANTHRACNOSE

(See color plate, page 11.)

This disease has been known in the United States for many years, and was



Common leaf spot of alfalfa. Small, circular, brown spots followed by leaf yellowing and leaf-drop characterize this disease. Older spots have a small, dark brown, raised disk in their centers.



Downy mildew of alfalfa. Upper left, healthy leaf; lower right, leaf shows chlorosis of infected portions. Leaflet at lower left shows characteristic color of fungus spore mass on underside.

EIGHT ALFALFA DISEASES and HOW TO RECOGNIZE THEM

The color photographs on this and the opposite page are intended as supplements to the descriptions given in the text, to make some of the most important alfalfa diseases more easily

identifiable. The grower should become familiar with these symptoms so that he can spot signs of disease before it becomes widespread in his alfalfa stands.

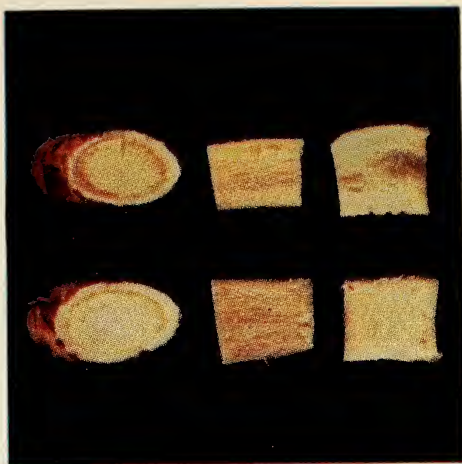
Bacterial wilt in an advanced stage of development shows severe stunting and yellowing.



Dwarf disease of alfalfa. Plant in center shows typical severe dwarfing and dark green color.

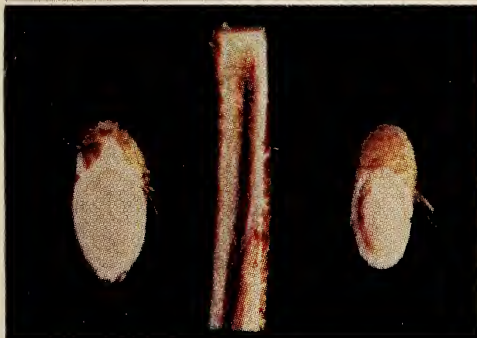


Comparison of internal root symptoms of bacterial wilt (upper row) and dwarf (bottom row). Left, diagonal root sections; center, surface of woody cylinder with bark removed; right, inner surface of bark showing brown spots in the case of bacterial wilt.



Top, typical stem lesions of southern anthracnose disease. Bottom, root symptoms of Fusarium wilt, showing, left, diagonal section of healthy root compared with similar section of diseased root, right. Note typical one-sided discoloration of the woody cylinder. Center shows red streak of invaded tissue as seen when bark is removed.

Top, *Stagonospora* crown and root rot. Thin layer of bark cut away to show internal symptoms. Infected roots do not usually rot until two to four months after the infection begins. Bottom, *Phytophthora* root rot with roots partially sectioned to show discoloration of invaded tissues. This is one of the most serious diseases of alfalfa in California.



found causing considerable damage in California in 1953. It has been identified in several fields in Imperial, Orange, and Santa Barbara counties, and more recently in the Sacramento Valley. Only alfalfa and certain clovers are affected. In the southern United States it occurs occasionally on crimson clover, subterranean clover, bur-clover, red clover and white sweet clover. It has not been observed on white clover (Ladino).

In the fields where anthracnose crown rot was observed, only part of the plants in the affected area were killed. The stem spot phase causes girdling and death of the stems with consequent loss in yield and quality. The full importance of the disease cannot be assessed until further observations are made. It has been observed most frequently upon the varieties Africa and Lahontan.

The disease is caused by a fungus, *Colletotrichum trifolii*. It may be spread by irrigation water or by implements carrying infected plant parts.

Symptoms. Anthracnose is seen on lower stems, leaves, and crowns of alfalfa. The spots on the stems and leaves are black and irregularly shaped. In advanced stages the spots become bleached in the center, and spore-producing bodies (acervuli) appear. On crowns, the rotted area is yellow to tan in color, often with a narrow band of reddish-brown tissue on the border of the advancing rot. Plants with anthracnose on crowns usually wilt and die. If it affects only the crowns, the disease is difficult to identify unless the grower is familiar with it. Microscopic examination is often necessary.

Control. The most effective control would be a resistant alfalfa variety. Since the disease is not at this time of great importance, resistance has not been investigated in California. Rotation to other crops for two years should be effective if all alfalfa and clover plants are destroyed before the alternate crop is planted.

COMMON LEAF SPOT

(See color plate, page 10.)

This most common leaf spot of alfalfa is caused by the fungus *Pseudopeziza medicaginis*. Known throughout the world, the disease is important in California in the spring and fall in all alfalfa-growing areas except those in the desert.

Symptoms. The fungus attacks the leaflets and occasionally the leafstalk and stems. The spots are dark brown in color and are $\frac{1}{16}$ to $\frac{1}{10}$ inch in diameter. Older spots have a small, dark-brown, raised disk in their centers. The basal leaves show the first spots, and the disease moves up the plant to higher leaves during favorable weather. Infected leaves become yellow, and drop from the plant. During long periods of moist, cool weather all but the uppermost leaves may drop. Hay produced from such alfalfa is low in protein and carotene.

The fungus survives dry weather by remaining in the leaves which drop to the ground. With abundant moisture, and temperatures between 60° and 75° F, the surviving fungus produces ascospores in the centers of the spots. These spores are ejected into the air. If they land on a leaf, they germinate to produce microscopic fungus threads which penetrate the leaf tissue. The spread of the fungus in the leaf tissue causes death of cells, and the result is the brown spot. Spores may be produced in the new spots in 10 to 14 days and, in turn, infect higher leaves. Infection does not occur during periods of high temperatures and low moisture.

Control. Following a heavy wave of infection, it may be profitable for a grower to cut his alfalfa somewhat before the normal time in order to save as many leaves as possible. The variety Caliverde has a good tolerance to the disease although some plants may be found to be heavily infected.

DOWNY MILDEW

(See color plate, page 10.)

Downy mildew is a disease caused by invasion of the plant tissue by the fungus *Peronospora trifoliorum*. The disease is widely distributed in the temperate regions of the world. It is important in California in the early spring.

Symptoms. The characteristic symptom is the light-green or yellow color of plant tissue invaded by the fungus. The diseased areas may be portions of leaflets, entire leaves, and even entire stems. The rate of plant growth and susceptibility determine the extent of invasion of the tissues. A rapidly growing plant shows only small areas of invasion on the leaves. Margins of affected leaves roll downward. When the entire stem is affected, all leaves and stem tissue are yellow. The stems are larger in diameter, and much shorter than normal. During periods of abundant moisture, with temperatures between 50° and 65° F, the fungus in the leaf tissues produces a large number of spores. Masses of spore-bearing stalks and spores ranging in color from gray to violet may completely cover the undersurface of the diseased leaves. The spores are carried by air currents, and those that fall on young leaves germinate to produce a microscopic fungus thread which penetrates into the leaf through the natural openings. Following sporulation, and in late stages of the disease, other fungi and bacteria may enter the diseased tissue and complete the destruction. Seedling alfalfa can be severely damaged by downy mildew. The more susceptible plants may die, and the remaining affected plants may be severely stunted. This stunting effect is evident in the slow recovery of such plants following cutting. The fungus survives the summer months either in the crowns of plants that are extremely susceptible or as resting spores (oöspores) in leaf and stem tissues on the soil.

Control. The only practical control is

the use of resistant varieties. In California Common, about 20 per cent of the plants are resistant. In the development of the variety Caliverde, selections were constantly made for resistance to downy mildew; thus, this variety has a very high percentage of resistant plants.

RUST

Alfalfa rust is caused by the fungus *Uromyces striatus medicaginis*. It is world-wide in distribution. In California the disease is common in the coastal areas during the summer months, and occurs sporadically in the interior valleys in late summer and fall. Infection is limited to alfalfa.

Symptoms. The fungus produces reddish-brown spore masses within the leaf tissue. These spore masses rupture the outer leaf tissue, and appear as a powdery mass on the surface. On dark-green leaves, a yellow halo of tissue may surround the spots. The pustules are commonly scattered over the leaf surface, but may be arranged in a circle about 1/4 inch in diameter. When the spores are touched, many adhere to the fingers, leaving a reddish mark. Rust is the only leaf spot disease of alfalfa with this characteristic. Stem infections are common under favorable weather conditions and when long intervals elapse between cuttings. Seed crops in some areas may be badly damaged. The presence of many spore pustules indicates that the plants may be severely damaged as a result of excessive loss of water through ruptures in leaves and stems and use of plant food by the fungus. The disease is favored by high humidity and temperatures between 70° and 85° F. When conditions are unfavorable for its development, the organism survives as spores or as fungus growth in the base of the stems.

Control. No practical means of control is known. When heavy infection occurs, it is best to cut for hay as soon as possible, even if the crop was originally intended for seed.

SCLEROTINIA ROT

The disease commonly referred to as Sclerotinia or cottony rot is caused by the fungus *Sclerotinia sclerotiorum*. It has been observed in a few fields in the central Sacramento Valley in the spring. The same fungus will attack the various clovers grown in California.

Symptoms. The fungus attacks the base of the stems and crown branches near the soil line, resulting in death of these tissues and rapid wilting of the tops of the plants. It has been seen most frequently attacking one to three plants in scattered spots in the field.

Abundant fungus growth occurs on the surface of the invaded tissues and appears as a white, cottony mat during moist weather. Small, hard, black, irregularly shaped bodies (sclerotia) are later formed in the mat, and may vary in size from $\frac{1}{8}$ to $\frac{1}{4}$ inch in length. Sclerotia are resting bodies that remain dormant during hot, dry weather. They germinate under cool, moist conditions to produce either fungus strands (mycelium) or small ($\frac{1}{4}$ inch) buff to pink, stalked, saucer-shaped, fruiting structures (apothecia) which emerge through a thin layer of soil covering the sclerotium. The apothecia produce masses of air-borne spores which can reproduce the fungus.

Spring black stem. Left stem and leaves show spots characteristic of active stage of disease. Dead stem, right, shows small, black, spore-bearing structures.



Control. The disease has been of minor importance in California, and no control measures are practiced.

SPRING BLACK STEM

The fungus *Ascochyta imperfecta* causes this disease which is commonly present throughout central and northern California in the winter and spring.

Symptoms. The fungus produces elongated, dark-brown to black lesions on the stems and petioles that are evident throughout the portion of the year when rains and cool temperatures prevail. Infection is often severe enough to kill stems and young buds. The leaf spotting phase is characterized by small, irregularly shaped, dark-brown to black spots that often coalesce to large blackened areas. Affected leaves usually turn yellow and drop from the plant. A complete invasion of the petiole often results in withering and death of the leaflets.

The spores that spread this fungus are produced in the fungus fruiting structures (pycnidia) on stems killed in the fall or winter. The pycnidia are evident as small, black spots partially embedded in the stem tissue which at this time is bleached to a tan color. Rain water is the agent responsible for spread of the spores.

Control. No control is practiced, and the disease rarely causes extensive damage except during the first spring growth.

MINOR FUNGUS DISEASES

Several fungi other than those described may cause leaf spots of alfalfa, but seem to be of little economic importance in California.

Stemphylium leaf spot, caused by *Stemphylium botryosum* (*Pleospora herbarum*), is most common in California during the spring and summer in the coastal regions. Moderate temperatures accompanied by high humidity favor development of the disease. The spot is tan to brown, somewhat irregular in shape,

and may show a target pattern. A single infection can involve as much as one-half the leaflet. Heavy infections may result in considerable defoliation.

Yellow leaf blotch is a leaf spot disease caused by the fungus *Pseudopeziza jonesii*. Young spots appear as yellow, elongated blotches between the main leaf veins. As the spot enlarges, the color changes to orange-yellow. Brown dots later appear in the central portion of the spot. These are fungus structures in which spores are produced. This disease is relatively rare in California.

Stagonospora leaf spot is caused by the same fungus as that causing a crown rot (p. 8). The leaf spots are $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter, and circular to somewhat irregular in outline. The central portion of the spot is pale buff, and the margin light brown in color. In advanced stages, very small, dark-brown spots are scattered in the affected area. These spots are the fruiting structures (pycnidia) of this fungus in which spores are produced that may be spread to adjacent leaves and plants by rain. The leaf spot phase of the disease is most common in the northern central valley in the early spring, following cool, moist weather.

Cercospora leaf spot is caused by the fungus *Cercospora zebrina* and occurs during warm, moist weather. It has been observed recently in the Sacramento and San Joaquin valleys, particularly on Lahontan, at a level of infection resulting in considerable defoliation.

The leaf spots are usually irregular in shape, brown to dark gray in color, and $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. The infection results in some yellow discoloration of the remainder of the leaf. When this occurs, the leaf will fall. Dark-colored, elongated areas of infection are usually present on petioles and stems.

SCALD

(See photograph, page 2.)

Scald is a disease of alfalfa associated

with excessive irrigation during the extremely hot summer months of August to October. The disease is an extremely important problem for the alfalfa industry in the Imperial and Palo Verde valleys where it occurs frequently on the heavier type soils which do not drain quickly.

The primary cause is thought to be physiological in nature. It has been determined experimentally that the damage is not the result of high temperatures alone, but of the interaction of high temperatures and flooding. If land is not flooded excessively, scald will not occur. Scald appears to be the same as "drowning" of plants which commonly occurs in low spots, except that in hot weather, plants die much more rapidly.

Symptoms. This disease does not have a typical set of symptoms by which it may be identified. Affected plants are usually yellow and stunted, and fail to recover following irrigation. In many cases, affected plants may die within a week after irrigation. Usually plants growing on the borders are not affected. The vascular system, particularly the xylem or water-conducting tissues, becomes brown in color. Roots of affected plants break down and are decomposed quite rapidly by soil organisms. Since alfalfa roots contain a large amount of starch, bacteria begin to grow very rapidly upon affected roots, causing them to become slimy and putrid. Nearly all plants in the area receiving an excess of irrigation water are killed, in contrast to *Rhizoctonia* root canker, which usually does not kill all plants at the same time.

Control. Research conducted at the Imperial Valley Experiment Station has shown that when air temperatures were as high as 116° to 118° F, scald did not occur except when plots were flooded for at least 36 hours. Ordinarily, water would not stand on well-drained land that long. These experiments indicated that attempts to control the problem should be aimed at prevention.

Preventing leaks in irrigation ditches, shortening the length of the area to be irrigated, and careful leveling of land before planting should be helpful. Irrigation at night when soil temperatures are at a minimum might be a useful practice. Some growers stop irrigation during August to October to prevent scald and growth of high-temperature water grasses, but because of high soil temperature and the drying effect of nonirrigated soil, fields suffer a high percentage of stand loss as a result of the drying action alone. Alfalfa has been irrigated in short runs throughout the summer at the Imperial Valley Field Station for the past several years without trouble from scald. Some growers have also been able to maintain a producing stand of alfalfa during the summer by careful irrigation practices.

Scald is more severe on alfalfa which has been cut immediately before irrigation. Avoiding irrigation immediately after cutting may be helpful. Plants growing in areas compressed by wheels of tractors or trucks are much more susceptible to scald.

Replanting alfalfa during October to November in areas affected by scald has been successful in re-establishing the stand.

SEEDLING DISEASES

Several soil fungi (*Pythium* spp., *Rhizoctonia solani* and *Fusarium roseum*) may attack alfalfa seedlings under favorable environment. Death of seedlings may occur before or after emergence from the soil. If the seedlings have emerged, the disease is characterized by a soft, water-soaked area on the stem just below the soil line. In California, these problems are most common in cool weather when the soil is excessively wet during the germination period. A few areas have difficulty in obtaining stands each year.

Control. Chemical seed treatment will be of benefit in areas where seedling dis-

eases are most common. The two chemicals that appear to be most successful in California are thiram (Arasan), at a dosage of 8 ounces per 100 pounds of seed, or dichlone (Phygon) at 4 ounces per 100 pounds. These recommendations are for dust treatments. For slurry treatment, use the slurry formulations of these products at the dosage recommended by the manufacturer.

NEMATODE DISEASES

Alfalfa is attacked by several kinds of nematodes. These are round worms, usually of microscopic size. The most important are the alfalfa stem nematode and the root-knot nematodes. Three species of root-knot nematodes are known to be able to live on alfalfa: the northern root-knot nematode (*Meloidogyne hapla*); the Javanese (*M. javanica*); and the cotton root-knot nematode (*M. incognita acrita*). In California, the northern species is most commonly encountered; the Javanese is present in some areas. The cotton root-knot nematode will live on alfalfa roots inoculated in the greenhouse, but is rarely found attacking them in the field.

The stem and bulb nematode, *Ditylenchus dipsaci*, includes a number of races, each of which is quite selective with regard to the plants it attacks. For example, the alfalfa race will sometimes attack certain clovers, but does not attack daffodils, garlic, oats, and onion, which are attacked by another race of the nematode.

Others, such as stubby-root, stylet, spiral, and root-lesion nematodes, are sometimes associated with the roots of alfalfa, but the extent of the damage that they may do has not been determined.

Alfalfa stem nematode

This nematode attacks the buds and stems of the alfalfa plant, resulting in reduced growth of stems. The infected stems are characterized by shortening of

the internodes and swelling of the stem tissues. Severely damaged plants have short, clublike growth. When plants are heavily attacked they may not produce any long stems suitable for harvest. The most conspicuous damage to alfalfa occurs early in the growing season when plant growth is relatively slow and moisture conditions favor activity of the nematode. Later in the season, growth may be fairly normal in infested plants, and some of the stems will reach normal length. In addition to reducing growth of the stems, the nematode contributes to loss of stand by weakening and eventually killing the plants. Heavily infested areas frequently exhibit poor stands, with short stems on the remaining plants.

Control. Injury to alfalfa by the stem nematode is most common in areas where alfalfa is grown frequently on the same land, with little or no crop rotation. The nematode is seldom a pest in areas where alfalfa is regularly rotated with such crops as beans, cotton, corn, sorghums, lettuce, carrots, tomatoes, and grains, provided host weeds are not present and there is an interval of about two to three years between alfalfa crops.

Two varieties resistant to the alfalfa stem nematode have been developed for use in Great Basin areas. These varieties,

Nemastan and Lahontan, and particularly the latter because of its resistance to both the spotted alfalfa aphid and the nematode, can be used successfully in infested fields where it is not feasible to secure control by crop rotation. No satisfactory chemical control methods for use against alfalfa stem nematode are available at present.

Root-knot nematodes

These nematodes cause the formation of galls or knots on the roots of alfalfa. The extent of damage to the root system is variable, and heavily infected plants may or may not show evidence of poor growth. The northern root-knot nematode causes formation of very small, distinct galls, while the other two species cause formation of relatively large galls.

Control. There is some evidence that the northern and the Javanese species cause damage to alfalfa in sandy soils in some parts of California. Exploratory control experiments with nematocidal chemicals indicate that it is possible to improve the stand and increase the yield of alfalfa in some nematode-infested fields by the use of preplanting soil treatments. Such treatments have not always been successful, and it is suggested that, in problem areas where root-knot nema-

Left, healthy alfalfa. Center, plant infested with stem nematode, showing shortened and swollen stem. Right, root-knot nematode. Note galls and swollen, irregular, small roots.



tode is suspected of causing injury to alfalfa, treated strips be compared with untreated areas before a decision is made to treat large acreages.

Because of its susceptibility to root-knot nematodes, alfalfa can maintain populations that will be injurious to subsequent susceptible crops. In some instances, however, alfalfa is a valuable rotation crop to reduce populations that would ordinarily be injurious to subsequent crops. For example, cotton in California is frequently injured by the cotton root-knot nematode, but when alfalfa is grown on land infested with this pest, its population is reduced because alfalfa is a poor host of this nematode.

It is therefore possible to recommend alfalfa as a rotation crop to control cotton root-knot nematode. This type of situation is not common, because many crop plants are attacked by both of the root-knot nematode species that attack alfalfa freely, and these nematodes are able to maintain high populations on alfalfa.

MINERAL DEFICIENCY DISEASES

If certain essential mineral nutrients are not available in the soil in sufficient quantities, the result is poor plant growth and, in some cases, characteristic plant symptoms not unlike those caused by fungi, viruses, etc. In some cases, supplying the necessary nutrients has not only restored normal growth, but has also doubled or tripled yields.

Potassium deficiency produces certain very characteristic symptoms in alfalfa. Affected plants show small, white dots, first on the younger leaves, later spreading to older leaves. The dots appear just inside the leaf margin, starting near the tip of the leaf, and later extend around the entire margin. In extreme cases the entire leaf margin will be dead. Growth of affected plants is very slow. Areas in which potassium deficiency may occur include the Sacramento-San Joa-

quin Delta and a section in Butte County.

The condition can be corrected by application of potassium in any of its commercially available forms. Rates from 500 to 1,000 pounds per acre of potassium sulfate have been required to secure plant response on some soils.

Phosphate deficiency does not produce such well-marked symptoms in the plant as does potassium deficiency. Affected plants make a slow growth and have a somewhat darker blue-green cast than normal. In extreme cases, plants may show a reddening of the leaves, particularly along the veins on the underside. This reddening may be produced by other causes, such as leafhopper injury, and should therefore not be taken as conclusive evidence of phosphate deficiency. Phosphate-deficient soils are widely scattered in California, and the areas cannot be well defined. Desert soils in particular are likely to be deficient if phosphate has not been applied.

Phosphate may be added as single or treble superphosphate or as liquid phosphoric acid. Annual application of about 40 to 80 pounds of actual P_2O_5 per acre will usually produce normal growth.

Sulfur deficiency in alfalfa is indicated by a yellowing which begins in the upper leaves and extends progressively to the lower ones. Nodulation may be poor on sulfur-deficient soils, and plant growth is very slow. Sulfur deficiencies occur in several areas of the Sacramento Valley and on the eastern side of the San Joaquin Valley.

Sulfur may be applied as gypsum or elemental sulfur or single superphosphate. If elemental sulfur is used, it should be worked into the soil to hasten the oxidation and plant response. Rates of 400 to 600 pounds of gypsum per acre are commonly applied to correct a deficiency.

Boron deficiency in alfalfa, while fairly common in eastern states, is rare in California. It does occur in the Tulelake area. Affected plants show a yellow-

ing or chlorosis of their upper parts. There may be a marked shortening of the upper internodes, producing a rosette appearance. Affected plants may fail to produce flowers.

Boron deficiency can be corrected by application of 20 to 30 pounds of borax per acre.

GENETIC DEFICIENCIES

Inbreeding of alfalfa results in various types of abnormal plants. Normally, where plants are allowed to open-pollinate, these genetic deficiencies are minor. Only two occur frequently enough to be noted.

"Carrot top." This name is applied to plants in which the flowers have no petals, and the flower heads are much branched instead of compact, resembling somewhat the seed head of a carrot plant. The color is greenish yellow. In some cases, the branching is less pronounced and some of the flowers may have petals. Carrot top is strictly the result of a genetic deficiency in the plant. Occasional plants of this type may appear in any variety, but they occur most commonly in Caliverde and Buffalo. The abnormality in no way affects forage production, and the proportion of affected plants is too low to affect seed production. Since affected plants bear little or no seed, the proportion will not increase.

Genetic leafspot. Under conditions of rather low temperatures, that is, only slightly above freezing, certain alfalfa plants develop gray to white spots on the leaves. This spotting is genetic in nature, and develops only at low temperatures. When temperatures become warm enough for active growth, normal leaves are again produced.

BREEDING FOR DISEASE RESISTANCE

Development of resistant varieties offers the best means of controlling certain of the alfalfa diseases. The feasibility of this method is well illustrated



Potassium deficiency causes white spotting of alfalfa leaves as shown above. (Photo courtesy American Potash Institute.)

by the present widespread use of varieties that have been bred for resistance to bacterial wilt. They include Ranger, Buffalo, and Vernal, for use in eastern and northern states, and Caliverde for use in California. In addition to being resistant to bacterial wilt, Caliverde has some resistance to common leafspot and mildew. Another release by the University of California, California Common 49, has tolerance to the dwarf disease.

One of the requirements of a program for breeding for disease resistance is to

Alfalfa plant at left shows carrot top symptoms. Note lack of petals, branched flower heads. Plant at right is healthy.



have a resistant strain (or at least individual plants) that will transmit resistance to the offspring. At present the University has a program aimed at locating satisfactory sources of resistance to several important alfalfa diseases. These include *Rhizoctonia* root and crown rot, *Phytophthora* root rot, *Fusarium* wilt, and root-knot nematode.

Satisfactory methods of testing large numbers of plants for their disease resistance is an essential part of the breeding program. This may require detailed studies of the behavior of the disease-causing organism itself as well as its relation to the plant host. Satisfactory testing methods have been worked out for many of the important diseases of alfalfa, and the work is being continued.

As satisfactory sources of disease resistance and methods of testing for it

become available, breeding for prevention of important diseases will become a part of the improvement program. To be satisfactory, a new variety must retain the high level of productivity, as well as the disease resistance, of any variety it is to replace. Thus as we reach higher levels of improvement in a variety, each new level requires an increasing amount of testing of large volumes of material in order to achieve an additional improvement.

While improved varieties can make and are making a contribution to alfalfa production, it should be borne in mind that the new varieties cannot solve all the problems. For example, disease resistance will not solve the problems of poor soil and unfavorable water conditions, nor can it compensate for poor management practices.

In order that the information in our publications may be more intelligible, it is sometimes necessary to use trade names of products and equipment rather than complicated descriptive or chemical identifications. In so doing, it is unavoidable in some cases that similar products which are on the market under other trade names may not be cited. No endorsement of named products is intended nor is criticism implied of similar products which are not mentioned.